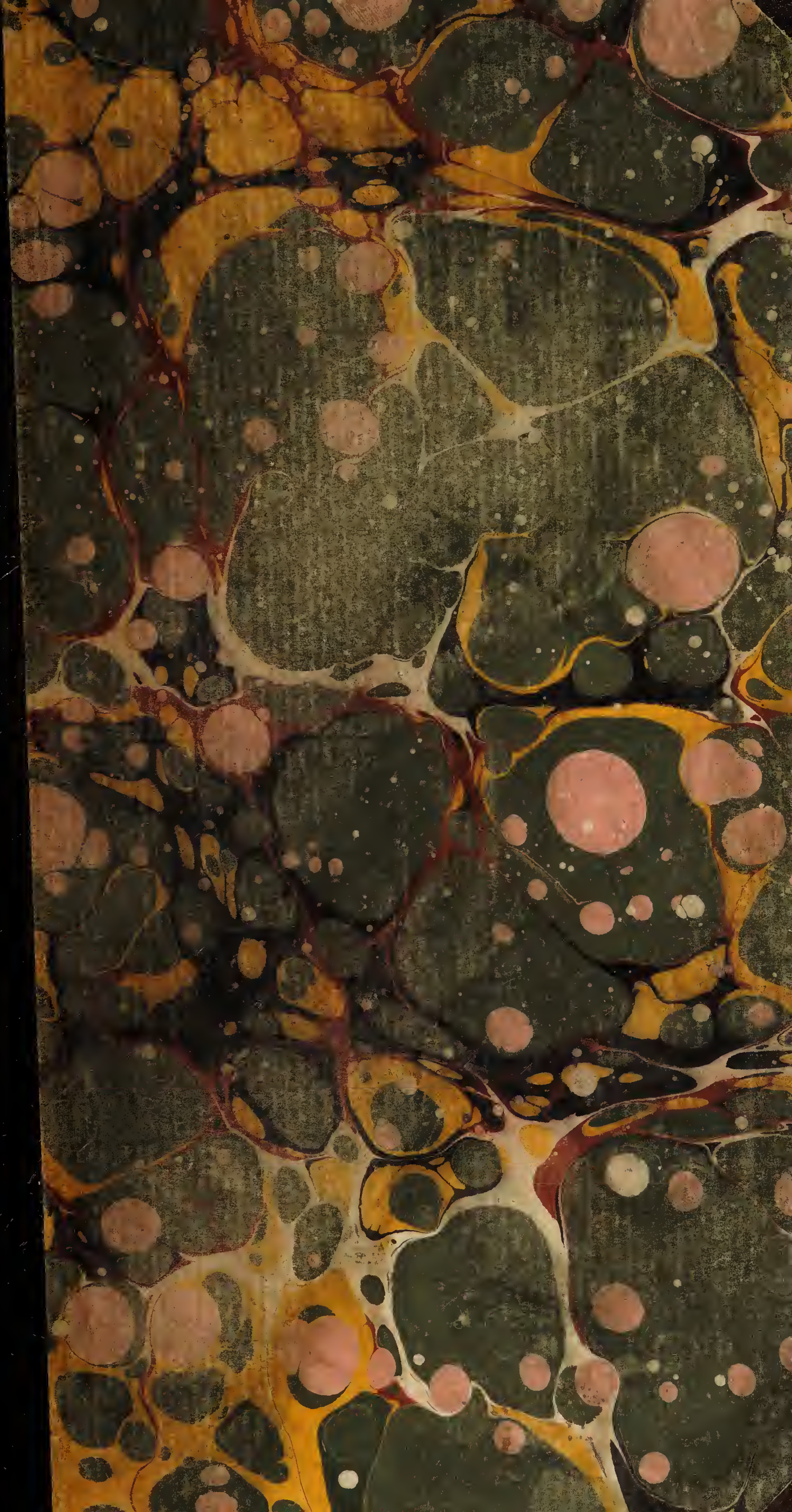

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DOUBTS

CONCERNING THE

INVERSION OF OBJECTS

ON THE

RETINA.

By MARMADUKE BERDOE, *M. D.*

Qu' il eſt heureux de ſcavoir douter! Un ſage ſepticiſme prend ſa ſource dans l'obſervation.—

ROBERT.

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THE ancients regarded the ſenſe of ſeeing as the moſt aſtoniſhing of human phænomena, and authors in general have had the moſt ſublime ideas concerning it. To go back to the ſchools and doctrine of the ancients, we find, that the Peripatetics and Stoics defined viſion to be an emiſſion of rays darting from the eyes, which conjointly with the light of the exterior air, ſeized

A 2 the

the objects as it were, and by that means render'd them viſible. Being reflected back again on the eye with a new modification, and by their union with the object, the rays cauſe an impreſſion on the pupilla, and produce the ſenſation of the object. This they attempted to prove by the following circumſtances. By the natural luſtre of the eye. They obſerved alſo that we perceive a cloud or miſt which is a great way from us, without diſtinguiſhing that which ſurrounds us. That we don't perceive an object which is on the pupilla. That the eyes are weakened by regarding an object for a long time, which they ſuppoſed to be owing to the quantity of rays emanating from them. That ſome animals have the property of ſeeing in the night.

The Epicureans imagined that viſion conſiſted in an emanation of corporeal atoms from the ſurfaces of bodies. They believed in a kind of atomical influx, which evaporated from the intimate parts of bodies, and at length arrived at the eye. Their principal reaſons were, 1ſt, That the object ſhould neceſſarily be connected with the power of ſeeing, for as the object has no union of itſelf, it ſhould be united to that ſomething which repreſents it, and which comes from its ſubſtance by a perpetual egreſſion. 2dly, That old men often ſee objects which are far removed, better than thoſe which are nearer to them. 3dly, They imagined that all viſible objects imprinted a perfect image of themſelves, in the ambient air, and that this image form'd another ſtill ſmaller, that again forming another, till by a ſucceſſive ſeries of objects, they at length reached the cryſtaline humor of the eye, which they conſidered as the principal inſtrument of viſion. —This progreſſion correſponds with the ſentiments of Ariſtotle, in his chapter, de aſpectu. Although the chain of images imagined by the ancients has been conſidered as a chimera, yet the ideas of Ariſtotle may very well be reconciled to thoſe of Deſcartes and Newton. For they all three ſuppoſe a medium.

The ſun, ſays Deſcartes, preſſes the ſubtile matter found thro' the vaſt compaſs of the world, whoſe vibrations reflected from the ſurfaces of this matter, are communicated to the eye, and from thence to the ſenſorium-commune. Newton ſuppoſes viſion to be owing chiefly to the vibrations of an exceeding thin medium, which by means of the rays of light are put in motion on the bottom of the eye. This impreſſion communicating again by the filaments of the optic nerves, to the ſenſorium-commune, conſtitutes the ſight. The celebrated Kepler, in his ingenious purſuits on this ſubject, wrote his *Paralipomena ad Vitellionem*, and reduced the laws of viſion to thoſe certain and, as he thought, invariable rules, which form the preſent ſyſtems of the moderns. He probably was indebted to the hints given by John Baptiſt Porta, for the diſcovery: who firſt obſerved the phænomena of the repreſentations of objects in the camera obſcura. The rays of light reflected from the ſurfaces of objects, ſtrike on the external membrane of the eye, and paſſing thro' the different humors of this organ, they are ſubjected to different refractions before they can ſtimulate the retina. The impreſſions made on this expanſion of the optic nerves, are conveyed to the ſenſorium-commune.

The inverſion of the objects perceived by John Baptiſt Porta, in the camera obſcura, and the experiment made by Kepler with the eye of a calf or ox, (deprived of its exterior membranes, and applied to the hole thro' which the rays of light enter into the room,) ſubjected the laws of viſion to a very great inconvenience, of which the ancients had not the leaſt idea. Kepler perceived in the eye the inverted ſituation of objects on the retina; he ſaw them inverted alſo on the wall of the camera obſcura, from which he he concluded, that we actually do ſee objects in an oppoſed ſituation to what they are in nature. He obſerved alſo, that the ſuperior faculties of the ſoul could rectify ſo apparent an error, by that divine influence which they have over the body, and ſhew all objects to us in their true and perfect ſituation. His ſuppoſitions were confirmed by the received laws of reflection and refraction, and by the different denſities of the humors of the eye.

Let us ſuppoſe a ray of light, A a, which marks the point of the arrow A B, reflected through the air on the tranſparent ſurface of the cornea R S, figure 1. It is an axiom in the laws of optics, that a ray of light paſſing from a rare into a denſer medium, approaches the perpendicular line, and on the contrary recedes from the ſame, when paſſing from a denſe into a rarer medium. —The rays of light, A R B S, are contracted into a ſmaller ſpace as they approach the tranſparent cornea, and on entering into the aqueous humor, whoſe medium is denſer than the air, they are drawn nearer to the perpendicular. In traverſing the cryſtalline K, they are more powerfully attracted by the ſame laws of refractions, as the humor of the cryſtalline is more denſe than the aqueous. But when the rays paſs into the vitreous humour, a medium leſs denſe than the cryſtalline, they diverge from the perpendicular line and continuing themſelves to the bottom of the eye, paint on the retina the inverted picture of the object, A B, as at I L.—The celebrated experiment of Mr. Kepler with the eye of an animal, being apparently confirm'd by the laws of refraction in the different mediums, aſſured him ſtill more of the reality of this inverſion. It was the means likewiſe of eſtabliſhing another received axiom in the viſual laws, namely, That without the paintings of objects on the retina, viſion muſt be imperfect.

According to the moſt modern improvements and diſcoveries, this ſenſe has ſtill been ſubjected to ſeveral inconveniencies, and various and indefatigable have been the enquiries of different authors to reconcile them. The inverſion of objects on the retina ſurprized all the philoſophers, and each by a different road have endeavour'd to explore the hidden paths of ſuch a ſeeming contradiction in nature.

Deſcartes, endeavors in his whole ſyſtem of viſion to reconcile the inverſion of objects, and imagined that the uncertain ſenſe of ſeeing, was ſubjected to the much more certain one of feeling, confirming his ideas by the experiment of a blind man, who holds in his hands two ſticks croſſing each other, by which he determines the impulſe of an agent to be on the left, which he felt on the right, and on the right when he felt it on the left.

M. le Cat, in his Eſſay on the Senſes, ſays, that the ſoul ought to ſee the rays of light, or rather ſhe ought to feel them in the different parts of the eye, as ſhe feels the fire, which affects different parts of the hand, for if the fire burns my thumb or little finger, my ſoul is not deceived. The repreſentation of objects are turned upſide-down on the retina, notwithſtanding which we ſee them in their true and natural ſituation. I would aſk then, ſays he, What becomes of the juſtneſs of my ſoul's judgment? Or rather, by what means does ſhe correct herſelf, ſo as not to judge conformable to the ſituation and impreſſions of objects on the retina, but to ſhew them to us as they are in nature? Or how can ſhe determine the impreſſion to come from below, which is above, or that to be on the right which comes from the left of the object on the retina? The great maſter that the ſoul has followed is the ſentiment of the touch. The ſenſe of feeling is alone the competent and ſovereign judge of the ſituation of bodies; it is by this maſter that we are firſt inſtructed that we walk upright, and from this firſt rule he has given us the idea of the true ſituation of other bodies. To theſe remarks M. le Cat ſubjoins ſome others, ſuch as the probability of a man being born blind, and afterwards couched and reſtored to ſight, having obſerved this inverſion of the objects. He is of opinion that the ſoul does really ſee objects inverted, and he ſays he caught her once in the very fact.

M. de Buffon calls the ſight a kind of touch, tho' eſſentially different from the common touch. For, ſays our learned philoſopher, if we touch any body with our hands or body, we judge by contact; but we may touch with our eyes at whatever diſtance the object is placed, provided only it is capable of reflecting a ſufficient quantity of light to make an impreſſion on the eye, and be contained within the angle of one minute. He imagines the inverſion to be owing to a defect in the formation of the eye.

The ſentiments of the Abbé Nolet on this matter, are by no means conformable to the opinion of the former gentlemen. I ſhall give what he ſays on that head from his own words : " *N'imaginons donc pas, comme on la'ſait, contre toute vraiſemblance, que nous voyons naturellement les objets renverſès, & que cen'eſt que par l'habitude et a force d'experience, que nous apprenons à bien juger de leurs ſituations. Les enfans et les animaux nouveaux nès, nous donnent des preuves du contraire dans les premiers movemens qu'ils ſont pour exprimer leurs beſoins, et leurs deſirs. Diſons plutôt qu'il eſt impoſſible que nous voyons jamais les objets autrement que dans leurs ſituations naturelles avec des rayons qui ſe croiſſent en entrant dans l'oeil.*" And he ſays again, " *Si lòn sétone devoir les objets droits quand on ſcait qùels ſe repreſentent toujours renverſes dans nos yeux, c'eſt qu'on confonde mal a propos, l'impreſſion qui ſe fait ſur l'oeil ou l'organe, avec le jugement de l'ame qui la ſuit.*"

Le Chevalier de Jaucourt ſays, that children have imperfect ſight till near ſix or ſeven weeks after their birth, and this he accounts for as follows. The eyes of children which come into the world have been ſhut for nine months, the cornea has not been able to acquire its external convexity. The veſſels through which the watery humors are filter'd, are not yet appropriated to this office. It is not then till ſome time after the birth that a ſufficient quantity of aqueous humors are collected to ſwell and fill up the two chambers of the eye and dilate the cornea, ſo as by puſhing it outwards to deſtroy the folds of its ſurface, and by a a more powerful compreſſion render the membranes thinner. Children by exerciſe fortify and ſtrengthen their eyes, tho' they cannot form an exact and true idea of each different impulſe, for the firſt defect of this ſenſe is to render every object in an inverted ſituation. Before they can aſcertain by the touch the true poſition of objects, and particularly of thoſe which are relative to their own bodies, they ſee at top what is at bottom, and at bottom that part of the object which ſhould be at top, and ſo receive by the eyes a falſe idea of their true poſitions. The firſt error therefore, ſays the Chevalier, is occaſioned by the defective formation of the eyes, on the bottom of which the objects paint themſelves in an inverted ſituation, for the luminous rays, which form the images of theſe ſame objects, cannot enter into the eyes by a decuſſation thro' the ſmall aperture of the iris. He confirms his aſſertions by the experiments made in the dark chamber. Perhaps it may be objected, he ſays again, that perſons who have been born blind, and afterwards reſtored to ſight, have not obſerved the inverted poſition of objects. To which I anſwer, Theſe blind men had been accuſtomed all their life time to the touch of objects, and by that means had form'd ſuch a certain judgment of their ſituation, that their ſouls became leſs ſubject to miſtake than others. For if the ſenſe of the touch did not correct and rectify the ſight, we ſhould for ever be deceived relative to the true poſition of objects, their number and places; we ſhould judge them inverted, or double; we ſhould gueſs the objects on the right to be on the left of the place they actually occupied, and if inſtead of two eyes we had two hundred, we ſhould ſtill judge the objects to be ſimple tho' we ſaw them by as many different multiplications. With the only ſenſe of ſight we ſhould equally be deceived relative to the diſtances, and without the touch, all objects would appear to be within our eyes, becauſe the images of objects are actually ſo; nor can we judge otherwiſe 'till we have meaſured the diſtance by ſtretching out our hands, or going from one place to another. Theſe are the ſure and certain leſſons by which we acquire juſt ideas of the reſpective diſtance and magnitude of objects. If then they aſk me why I ſee objects in their true poſitions, notwithſtanding they are inverted on the retina, I anſwer, that it is by uſe alone, joined to the ſentiment of the touch, that ſuch error is duely rectified.

The more modern productions of Dr. Porterfield and Mr. Reid, leave us not without our doubts, as the former allows the inverted *icon* on the retina, but ſuppoſes that the ſoul does not judge from the actual poſition of the object. The latter ſeems to conform to the general idea or axiom in the viſual laws, viz. That without the paintings of objects on the optic nerves or retina, viſion muſt be imperfect, but does not altogether agree with the general notions of the ſoul's judgment, and ſuppoſes viſion to be an immediate perception.

The little ſatisfaction I could procure myſelf from books towards the inveſtigation of this apparent contradiction in nature's works, made me give over all thoughts of accompliſhing it by any hints I might receive from others. I ſearched into the moſt reputed authors on that ſubject, Grimaldi, Newton, Molineux, Aquillioni, Marſennes, Scheiner, Gregory, Smith, De la Hire, Marriot, &c. &c. &c. each had their turn, but none afforded me any ſatisfactory arguments, or mark'd out a probable track to guide me in my purſuits. For this reaſon I left them all, and reſolved only to guide myſelf by ſuch experiments in dioptrics, as I could afterwards confirm by obſerving in what manner I was affected.

The ſectators of Kepler, (as indeed every author who has followed this ſyſtem of the inverſion of objects on the retina,) have contented themſelves with general proofs, ſuch as experiments made in the camera obſcura. They have adapted eyes (whoſe external membranes have been cut away) to the aperture in a room thro' which the rays of light entered, and have obſerved the inverſion of objects as deſcribed by Kepler and Deſcartes. Contented with this they have ceaſed their purſuits. But I have aſſured myſelf that very little certainty of inverſion of objects in the eye ought to be taken from this experiment, for the ſame phænomena will conſtantly ſucceed from the application of a ſimple convex lens, or a glaſs globe filled with water, or indeed any tranſparent ſpherical object, whoſe convexity collects a greater number of rays of light than the ſame diameter could were it a plane ſurface. Should the rays of light paſs into a dark room, thro' a ſmall aperture before which a convex lens is placed, the objects will ceaſe to appear on the walls, but will paint themſelves on a paper at a ſmall diſtance from the lens in the ſame inverted ſituation. Place at a proper diſtance from its focus a lens of the ſame form and diameter, and the objects will diſappear on the paper, but will preſent themſelves to the eye of the ſpectator that looks thro' the lens in their natural ſituation.

Suppoſe the rays of light (whoſe properties are always to move in ſtraight lines) ſhould be reflected from an object as at A B, fig. 2, the converging rays paſſing thro' the hole of the camera obſcura will decuſſate and paint an inverted icon of the different objects on the oppoſite wall of the room C D. But if a ſpectator placed in the chamber at E, ſhould view the external object A B thro' the aperture M N, it is certain he will ſee the object A B, in its natural ſituation at F G. It is no difficult matter to account for this circumſtance. The rays of light which form a converging cone, continually purſuing the ſame direction, ſtrike the eye of the ſpectator, the diameter of whoſe pupil is infinitely ſmall compared to the diameter of the aperture M N, of the camera obſcura. The ſpectator muſt conſequently ſee the object A B under a much ſmaller angle than that thro' which it enters to throw itſelf on the wall C D. Obſerve that the rays of light do not diverge, but are repreſented at the bottom of the eye,

N.° 1.

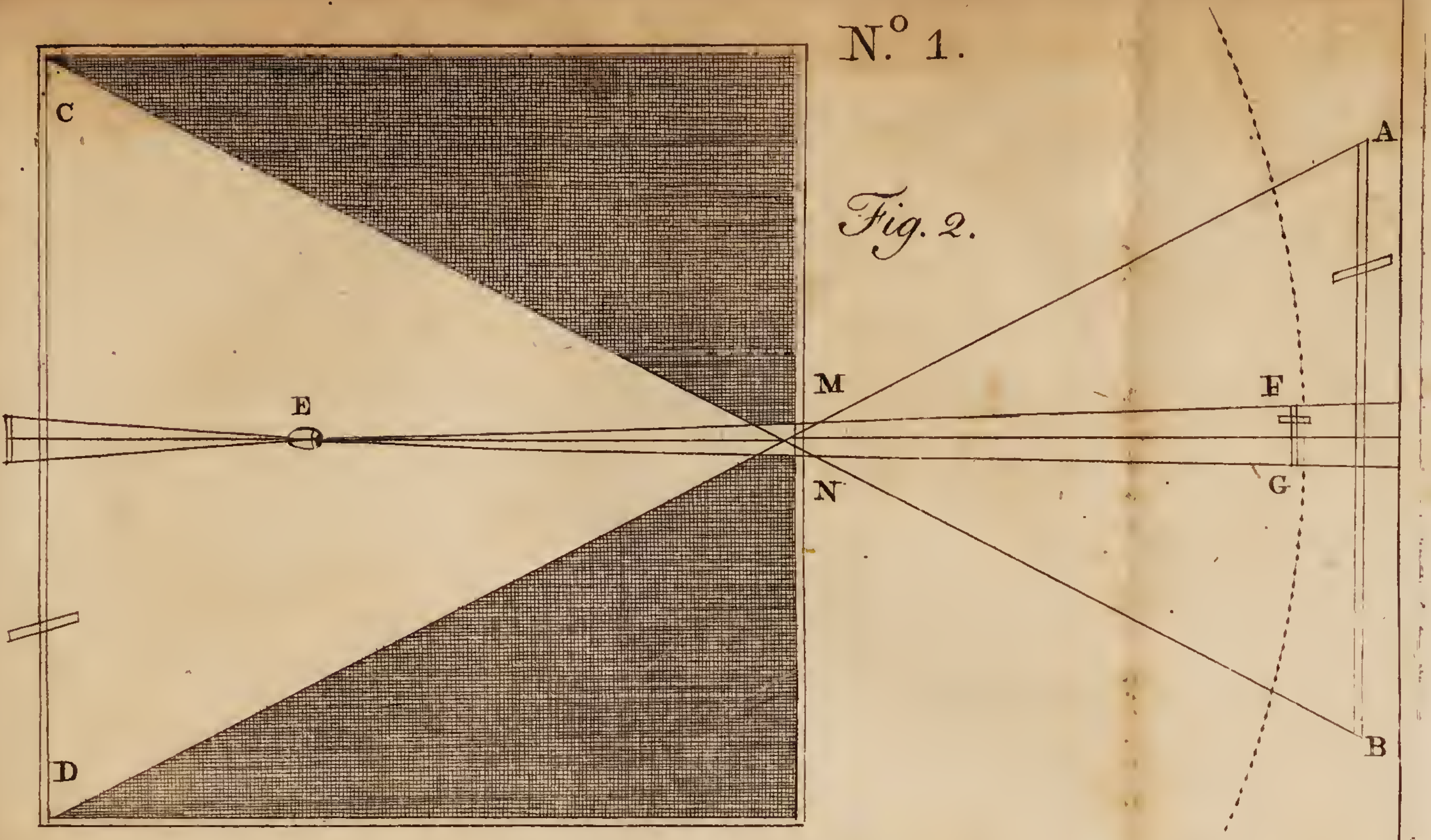
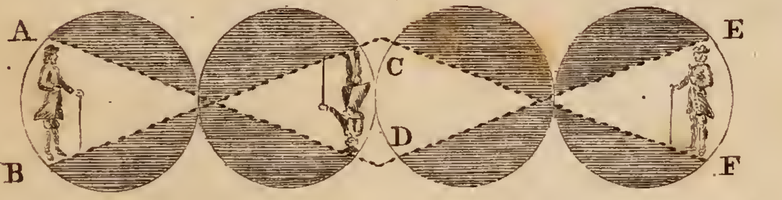


Fig. 2.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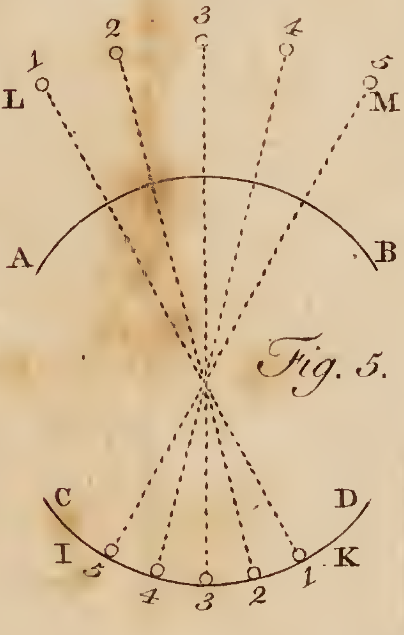
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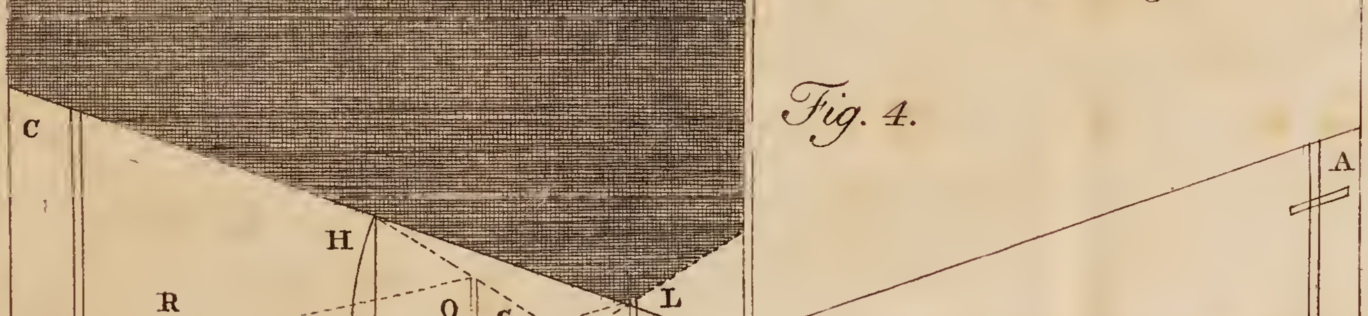


Fig. 4.

as the centre of the circle, or the point of the angle form'd by the union of the rays which come from the top and bottom of the object.

If we may judge with the celebrated Berkley, the eye is capable of conſidering the different manners, or rather the different poſitions of objects, muſt cauſe various ſenſations on the optic nerve. For if an object in an erect poſition will cauſe a certain and determined impreſſion on the organ of ſight, and the ſame object in an inverted ſituation will cauſe another ſenſation, by no means conformable, but utterly oppoſed, the ſoul then eſtimates and confirms the different impreſſions which are made on the retina. Let us ſuppoſe for a moment, that in the laws of viſion as taught by Kepler, the inverted icon muſt neceſſarily paint itſelf on the retina, are we to conclude from thence, that we cannot judge of the manner in which the eye is affected, and perceive it to be different when an object turn'd upſidedown preſents itſelf on the retina in an erect poſition. For if the laws of viſion, according to Kepler, were the only certain, and the paintings of objects on the retina the pure ſource of ſight, admitting even that the ſoul rectifies this natural error, occaſioned by the inverſion of the object, as repreſented on the expanſion of the optic nerve, ſhe muſt ſtill be differently affected when the object changes its poſition. To put this matter in a clearer point of view. I ſuppoſe a man, A B, fig. 3. walking at a ſmall diſtance from the ſpectator, whoſe eye examines him, and receives, according to Kepler, the inverted repreſentation of the object on the retina at C D. Should I ſuppoſe, on the contrary, a man ſtanding on his head as at C D, his image muſt be painted on the ſpectator's eye in an erect ſituation, as at E F. Obſervation will confirm in the moſt evident manner, to every individual, (and which is better than a thouſand experiments) that I diſtinguiſh in the moſt clear and perſpicuous manner, the change of poſition in a man, who ſtands alternately on his head or feet. This diſtinction, according to the ſectators of Kepler, depends on the ſuperior powers of the ſoul, which correct the errors of our ſight, and appropriate them to our judgment. According to their ſyſtem, it is the active principle of the ſoul which corrects that inverſion of the object which is form'd on the retina, for, ſay they, the ſoul takes cogniſance of objects by the progreſſion of right lines. Should we ſuppoſe the repreſentation of the figure A B, to be inverted on the retina C D, yet by the progreſſion of the ſame lines the object muſt be conveyed to the ſenſorium commune as at E F, and again, if he ſtood upon his head, the ſpectator could not by the ſame progreſſion of lines ſee him in any other poſition than ſtanding on his head. All this ſeems conformable to obſervation. But I cannot help drawing a concluſion which muſt limit the active principle of the ſoul. For as ſhe conſtantly oppoſes this repreſentation of objects on the optic nerves, the ſoul is only active in reſpect to the mutations ſhe cauſes in the poſition of the object, otherwiſe ſhe enjoys no more than a paſſive privilege, ſince ſhe mechanically oppoſes the ſituation in which the object is painted on the retina. To explain myſelf: If either the intelligent principle by which we form to ourſelves the juſt idea of the ſhape, color, and extenſion of external objects, or if the ſoul judges conſtantly by a ſimple correction of the paintings of objects only, does ſhe do more than change their ſituation, by oppoſing and inverting the order of their poſition on the retina? The perceptive and active powers of the ſoul, which conſtitute the moſt brilliant part of the Keplerian ſyſtem, are limitted to a very narrow compaſs. Without any prepoſſeſſions in favor of a new ſyſtem, does that of Kepler produce any thing more in reality than the power of the ſoul oppoſing the poſition of objects on the retina? An object placed at A B, would by the different refractions which the rays of light undergo in paſſing thro' the humors of the eye, be repreſented on the retina in the poſition C D, a circumſtance, ſay they, incconteſtable; and proved by the ſanction of experiments made in the camera obſcura. The inverſion of the object on the retina, (by no ways conformable to our manner of ſeeing) ſurprized our celebrated obſerver, and the circumſtance embarraſſed him to account for its cauſe, and appeared ſo manifeſtly evident in the experiment of the eye applied to the hole of the camera obſcura, that it induced him to look on it as ſomething divine, or owing its influence to the ſuperior faculties of the ſoul entirely. Change the poſition of an external object in what manner you will, yet according to the ſyſtem of Kepler, its poſition on the retina muſt be entirely oppoſed to its natural one; as again, the action of the ſoul in the ſenſorium commune will paſſively oppoſe its ſituation on the retina. Theſe circumſtances are ſo certain, that the ſectators of Kepler aſſure us, if there were no paintings of objects on the retina, there could be no viſion. The paintings of objects are always oppoſed to their natural ſituation, conſequently uncertain, unleſs, as he obſerves, the ſoul rectifies them, which it does by paſſively oppoſing their ſituation on the retina. I ſhall leave every one to make what reflections they pleaſe on this matter, and ſhall content myſelf with obſerving firſt, That the judgment of the ſoul, on the repreſentation of objects on the retina, correſponds with, and conforms to the ſituations of external repreſentations on the cornea and conjunctive membranes of the eye. If it be neceſſary to bring any farther proofs of ſo obvious a truth, as the external impreſſions made on the cornea, being the only one which is conformable to the true ſituation of objects in nature, the following experiment muſt put it beyond a doubt.

Let the croſs, A B C D, fig. 4, repreſent the inverſion of the object which happens in the camera obſcura. Should a ſpectator placed within the room as at S, look on the repreſentation of the object C D, againſt the wall, it ought according to the rules of viſion eſtabliſh'd by Kepler, to be painted on the retina in its true poſition AB. For the rays of light reflected back from the wall C D, ſhould by the decuſſation of their rays in traverſing the different humors of the eye, repreſent the croſs in an inverted ſituation to C D, on the retina of the eye of the ſpectator S. But it is very evident from every man's own experience, that if I turn my eyes towards the wall, and look at the object C D, I ſee it in its inverted ſituation, as the eye would do at F. The ſectators of Kepler will, no doubt, obſerve that the ſame thing happens by the influence of the ſoul in correcting the inverſion of the object C D, on the retina of the ſpectator S, ſo that he ſees it in its true poſition C D. The rays of light when collected by a concave mirror at H K, as they enter the aperture of the dark chamber, and reflected back, will, as they diverge beyond the focal point, repreſent the image on the wall in its true poſition as at L M, ſo that if we look at the object O P, from the eye R, our ideas will correſpond with its inverted ſituation, the ſame as we may ſee it in its true ſituation by the diverging rays L M, in the eye G. By this experiment we may learn, that the icons of different objects are to be repreſented in either an inverted or natural poſition as depending only on the manner in which the rays of light are reflected from the different ſurfaces of bodies. But it will be very neceſſary to obſerve, that theſe delineations of the objects never take place but by the diverging rays after they have paſſed the focal diſtance of the reflecting body.

According to Kepler's ſyſtem, the active principle of the ſoul is found to oppoſe and change the poſition of the object on the retina, be it what it will, without exception. Then why does the judgment of the ſoul, when it corrects the poſition of objects on the retina, ever conform to the ſituation of objects on the conjunctive membrane of the eye? Or are we to regard this active principle of the ſoul as limitted to the correcting of an error, by an inceſſant opoſition to the icon as repreſented on the retina of every individual? For the ſoul, according to this ſyſtem, is entirely paſſive, and Kepler might with much leſs myſtery have advanced, that every actual impreſſion made on the retina, was continued to the ſenſorium commune, by the progreſſion of the ſame lines, where its inverted ſituation was probably corrected. Should the paintings of objects be ſo very eſſential to the true cauſes of viſion, the active principle ought to confirm to us theſe repreſentations, or, if as Kepler affirms, the ſuperior influence of that innate principle by which we are animated, was conſcious of the error into which ſuch delineations might lead us, it ought again to change their poſitions, and repreſent them to us in their natural ſituations. If we conſider the ſoul as the moſt active principle of human nature, we make it abſurd to ſuppoſe her paſſive in any one circumſtance. The active powers of the ſoul can by no means argue a paſſive principle as ſhe is the judge or mediatrix of all our perceptions; was ſhe therefore to remain paſſive, ſuch perceptions muſt become imperfect to the body. I have endeavor'd to ſhew by the third and fourth experiments, that the active principle is limitted to a paſſive variation of the object by the Keplerian ſyſtem.

The way of reaſoning eſtabliſhed by Kepler may then be ſuſpected, yet the effect produced by it will ever be the ſame, for we can ſee objects but one way, and that muſt be in their natural poſition.

The firſt circumſtance that naturally occurs to every obſerver of the human eye is, that the exact repreſentations of all objects are naturally and exactly painted on the conjunctive membrane of the eye. The poſition of theſe objects will be found to agree invariably with the judgment of the ſoul. We are next led to conſider, that the eye, according to the Keplerian ſyſtem, muſt receive two diſtinct and oppoſed ſenſations. The firſt that natural and exact reſemblance of the object which is delineated on the extreme ſenſible membrane covering the cornea of the eye, and call'd by anatomiſts the conjunctive. The ſecond the ſuppoſed inverted icon of the object painting itſelf on the retina, and which the ſectators of Kepler look upon as abſolutely neceſſary to viſion. The eye thus receiving two diſtinct ſenſations, offers the following queſtion to our obſervation. Does the ſuperior influence which the ſoul has over the corporeal ſubſtance, lead her to judge of natural objects by the impreſſion which is made on the exterior or interior part of the eye?

eye? When we conſider that the ſenſes in general flow from the ſame ſource, that they are all founded on that innate ſenſibility which is given to the nerves, and that theſe nerves have an univerſal ſympathy among themſelves; I ſay then, we may conclude in fact that we have but one general ſenſe. This fundamental and univerſal ſenſe is the aggregate of thoſe univerſal impulſes which are made upon the nerves, and which are by them communicated to the ſenſorium commune. They are more refined as the reſpective organs are more eſſential to the preſervation of the individual, or uſeful to his exiſtence. The ſenſations are either acute, pleaſing, torpid, or inſenſible, in proportion as the nerve is more or leſs ſenſible in itſelf, or more or leſs bedew'd by the paſſive organ of the cellulary-membrane in which they are enfolded.

The eye, from its extreme vicinity to the brain, becomes in itſelf the moſt refined organ of the ſenſes; its nerves are not only the moſt conſiderable, but the moſt expoſed to the impreſſions of external objects, and its agent the pureſt ſubſtance in nature, the rays of light. Is it not ſurprizing, that of all the ſenſes, it is the only one whoſe phænomena have remained a profound myſtery? For the other ſenſes are known to be cauſed by the impulſe of different agents which affect them, and our ſenſations are deduced from their impreſſion on the nerves of the human body. The actual contact of objects determines their qualities and form, when examined by the ſenſes of feeling and taſting. The olfactory nerves are ſtimulated by certain particles floating in the air, the auditory by the vibrations of ſounds. The retina ſtimulated by the rays of light which are reflected from the external ſurface of bodies, is ſubjected to the general cauſe of impreſſions with our other ſenſes. Why then are we to ſuppoſe, that the paintings alone of objects on the retina do cauſe, or are eſſential to the laws of viſion? Has any one ſeen this painting on the retina? Mr. Marriotte pretends to have ſeen it on the retina of a cat, which he plunged into water. The different attempts I have made to aſcertain this circumſtance on the human eye of ſeveral perſons placed ſo as to receive a convenient degree of light, as alſo on different animals by laying them in a prone ſituation the better to receive the impreſſion of an object, never afforded me any thing certain on that ſubject. But I have found by experience, that the retina muſt receive the impulſe of the agent, to ſtimulate the fibrils of the optic nerves, or viſion will be imperfect without it. The truth of this aſſertion every perſon may prove upon himſelf. Let the perſon ſhut his eye, or keep within a dark room for a ſhort time, on coming out let him open his eyes to look with firmneſs and attention upon any luminous object, ſuch as particularly the ſun, or a candle, or a window thro' which the rays of light enter in abundance, the eye on being immediately cloſed will preſent ſeveral or one luminous globe, ſuppoſing he has examined the ſurface of the ſun; or if a window, its ſhape and form, which will laſt in proportion to the ſtimulus that has been made on the optic nerve. But if the ſtimulus has been very great, ſo as to affect the optic nerve, by a leſion in ſome part of it, then the perſon will perceive an opake ſpot, which may remain for ſometime unleſs the nerve does ſufficiently recover its ſenſibility, and then the dark ſpot will diſappear. It will be neceſſary to obſerve likewiſe, that theſe impreſſions which are cauſed by the actions of external cauſes on the optic nerves, will always appear to affect the retina in their true and natural poſition and never in an inverted ſituation.

The idea that objects are painted on the retina took its origin, as I have already mentioned, from the experiment made by Kepler with the eye of an ox or calf, ſtrip'd of its external covering, and adapted to the hole of the camera obſcura, on which the inverted repreſentations of the external landſcape were obſerved. In repeating the ſame experiment, the ſame inverſion of the object appeared to me, but I can by no means allow as a concluſion drawn from it, that the ſame thing happens in the human eye when we behold all natural objects. The inverſions of objects on the retina have produced many ingenious hypotheſes, which, like the ſyſtem itſelf muſt fall, if founded on an error. For where nature is ſimple and uniform in all her works, how can we reconcile ſuch ſyſtems to that general ſimplicity of her laws?

What I have juſt mentioned will be elucidated by the following experiments, which will alſo throw ſome more light on thoſe queſtions in which we propoſed to conſider, firſt, If the ſoul determined the natural ſituations of objects by the firſt impreſſions which are made on the cornea, or by the ſecond, or thoſe impreſſions made by the ſuppoſed paintings of objects on the retina. No one will, I imagine, deny the exiſtence of what I call the firſt impreſſions on the exterior membranes of the eye: it is a truth (like many others which I have mentioned) of which every one who chooſes to obſerve, may be aſſured of its veracity; as alſo, that theſe repreſentations of objects are always conformable to the judgment of the ſoul. I have examined with a ſcrupulous attention the eyes of ſeveral perſons in which the imaguncula of the object which the eye of the ſpectator was attentive to, did always correſpond with its exact ſituation.

Placing myſelf before a mirror, and holding ſome ſmall object between my eye and the glaſs, I could perceive the object delineated on the ſurface of my eye, in the exact ſituation I held it, that is to ſay, upright when I held it ſo, and inverted on changing its ſituation, or turning it upſide-down, the idea of its ſituation always formed in my mind the ſame poſition of the object as that in which I actually ſaw it, and in which it appeared on the exterior part of the eye. This ſufficiently convinced me, that our ideas do continually and invariably depend on the manner in which objects are repreſented on the cornea, juſt as the mirror repreſents the true poſition of external objects. It is obvious alſo, that the retina can receive no impreſſion from an external agent, without its firſt having made a due and ſenſible impulſe on the conjunctive. Now the nature of the human ſtructure is ſuch, that an impulſe given to two different nerves, or two different parts of the ſame nerve, will cauſe two ſeparate and diſtinct ſenſations. If the ſoul therefore can receive and judge of different impulſes, does it not appear that ſhe muſt be agitated in two different manners, by the poſition of objects on the conjunctive and the retina, for as ſhe is ſenſible to every impreſſion made on her meſſengers, the nerves, ſhe ought to be affected by every different impulſe. The conjunctive, or the external membrane of the eye, is a nervous veil of the moſt exquiſite ſenſibility, covering over the whole circle of the tranſparent cornea, and ſpreading itſelf on the tunica albuginea. This membrane does therefore, as a kind of ſtimulus, excite the ſoul to obſerve the impreſſions made on it by the rays of light, which are again more eſſentially confirm'd by theſe impulſes as they are carried on to the retina. To elucidate this matter more fully, let us ſuppoſe A B, fig. 5, to repreſent the exterior membrane of the eye, or the conjunctive; let C D ſignify the expanſion of the optic nerves on the retina. Let us ſuppoſe any body whatever moving before the eye in a ſlow direction, may reflect different cones of rays upon the conjunctive as it paſſes, at 1, 2, 3, 4, 5, in its courſe from L to M. We may ſuppoſe likewiſe, (according to the Carteſian and Keplerian ſyſtems of viſion) that theſe impulſes muſt affect the retina by the decuſſation of their rays, C D, as in 1, 2, 3, 4, 5, mark'd on that membrane. From this circumſtance it muſt manifeſtly follow, that the eye receives two oppoſed and different impulſions, excepting thoſe which are made in the central points, 3 M L, 3 I K. Were it really the caſe, that the paintings of every object muſt abſolutely be delineated on the retina to cauſe perfect viſion, and that ſuch delineation was always inverted, in ſuch caſe I am almoſt perſuaded in my own judgment, that the eye muſt be ſenſible of the two different impreſſions made on it, and muſt be followed by a confuſion in the faculties of this ſenſe. For the extreme ſenſibility of the external membrane, or the conjunctive, muſt render its affections of material conſequence to the ſenſations. But in fact, viſion in the human body is both perfect and imperfect. The manner in which I make this diſtinction is, by calling imperfect viſion all that circle of perceptions beheld by the tranſparent cornea; and perfect viſion that cone of rays which ſtimulates the retina, thro' the aperture of the iris. We have imperfect viſion when we open a book and regard the ſubject of the whole page, and perfect viſion is the explaining of it word by word.

The celebrated Sthaal, attributing to every different part an active and ſenſible faculty, ſays that the ſoul directs every movement of the body. It muſt appear almoſt evident to the obſervation of every one, that the optic nerves ſeem to poſſeſs a radiant and primitive ſenſibility intirely ſuperior to the influence of the will, or elſe men would have been endued with a power of ordering the different diameters of each iris, and regulating their contractions and dilitations. But theſe ſublime faculties of the ſoul are as infinitely ſuperior to that privilege which nature has given to us, of directing the different motions of our hands and feet, as the animating principle itſelf is ſuperior to the body. And here I ſhall beg leave to correct an error of the celebrated Dr. Whytt, who aſſures us, that each iris, by a ſympathetic power, always preſerves an equal and juſt proportion in their contractions and dilitations. But from an exact obſervation on the eyes, I have remark'd that they often differ very eſſentially in their reſpective dilitations, for ſometimes the aperture of the iris of one of the eyes ſhall be double that of the other. Although the apertures of the iris do in general correſpond in their diameters, yet when one or other of the eyes, either by a ſpontaneous inflammation, or a cold, or if the eye is blood-ſhot, from a blow or other cauſes, in ſuch caſe then, as the ſenſibility of the nerves are injured, the diameter of the iris of the injured eye is generally leſs than that which is not hurt. But in order to have perfect viſion, this extreme ſenſibility of the iris is evidently neceſſary, for as we are continually moving from place to place, it often happens that the eyes are affected by different cones of light falling on them, in which caſe the iris, when directed by the innate ſenſibility of each particular nerve, appropriates itſelf to each reſpective cone of rays. That every perſon may be enabled to confirm, what I here aſſert by obſervation, let them place themſelves before a mirror, having on the right and left hand a candle of the ſame ſize and length, let them burn till the wick becomes long, then ſnuff either one or other of the candles, without ſnuffing the other, and you will ſee the iris change its aperture and appropriate itſelf to the different ſtimulus; the ſame thing may be done by moving one or other of the candles farther from you. Having convinced myſelf from frequent experiments made in this manner, that each iris does really and evidently appropriate itſelf to the ſtimulus occaſioned by the different modulations of the light, I began next to conſider that theſe variations in their apertures muſt occaſion different confuſions in the ſenſe of ſeeing, ſuppoſing the objects were really inverted. For if we ſuppoſe the eye A B, fig. 6, turns to an object when the irides are unequal in their diameter, and fixes upon the object C, does it not follow that the object painted on the retina of the eye B, muſt bear a different proportion to that which is delineated on the retina of the eye A? For the rays of light, however changed by intervening bodies, do always purſue their rectilinear directions, and conſequently ought to form a much larger angle on the retina B, than A, on account of the increaſed diameter of the iris. If the painting of the object on the retina, as it ought to do, depends on the proportion'd apertures of the iris, then, when this aperture is larger, the delineation of the object ought in courſe to be increaſed. I know by experience, that the aperture of the camera obſcura changes the tranſparency and proportion of the objects on the wall of the room. Now if the ſoul judges not by this painting, but by the manner in which the eye is affected, ought ſhe not to

N.° 2.

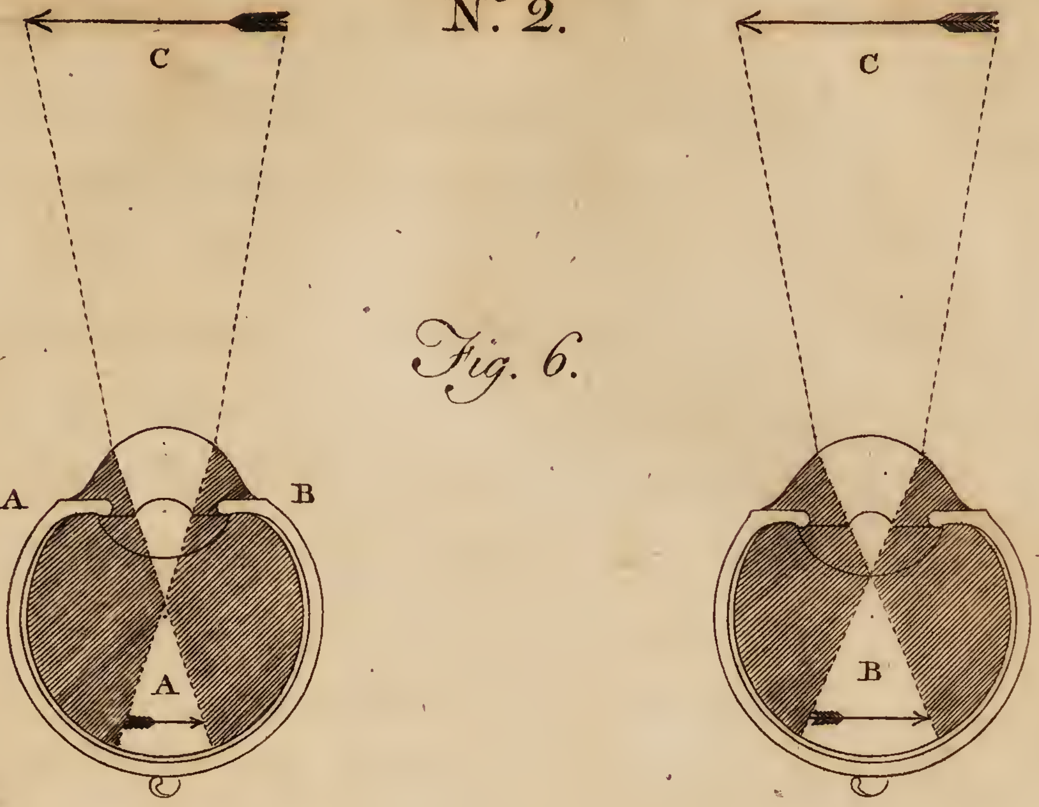


Fig. 6.

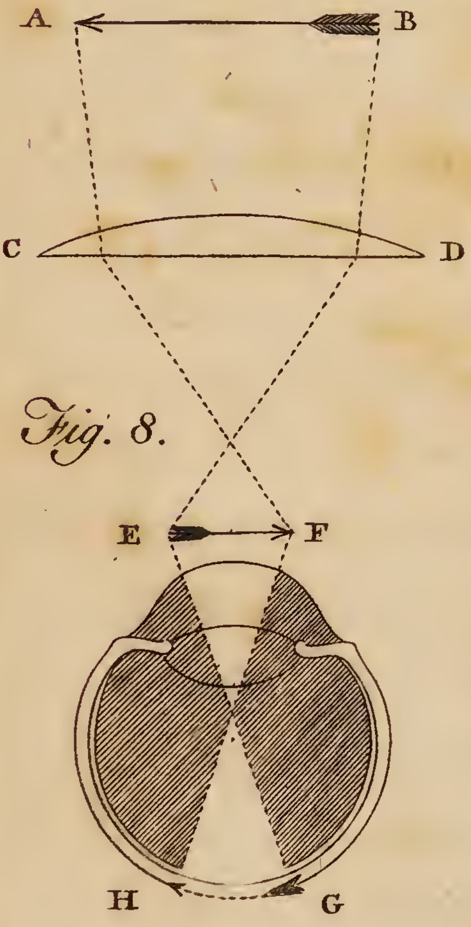
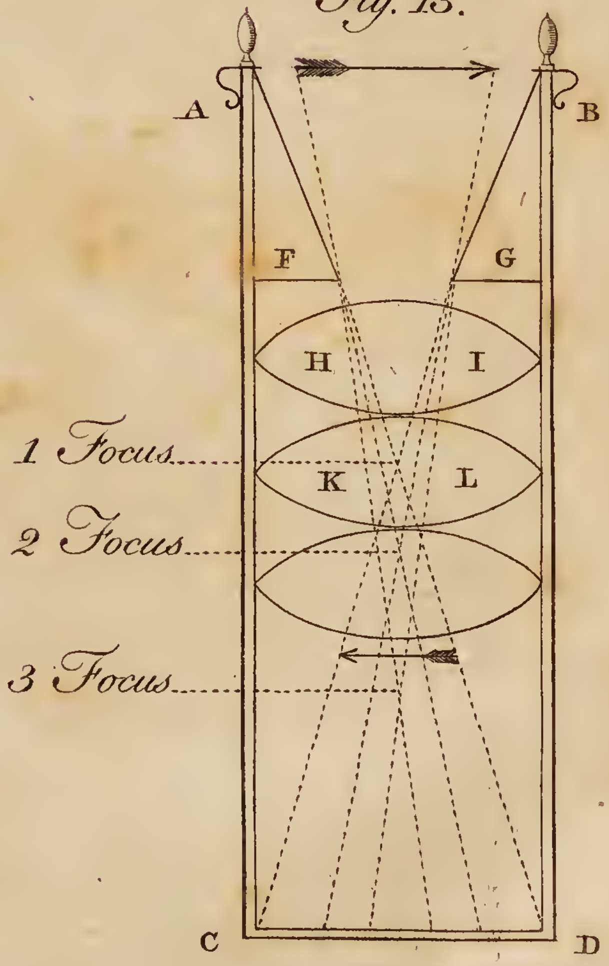


Fig. 8.

Fig. 13.



find the eye affected in a peculiar degree by the extenſion of the impulſe?

The many doubts which crouded on me at preſent, concerning the neceſſity for a delineation of the objects on the retina, and their inverſion, made me have recourſe again to the camera obſcura. I prepared the eye of an ox, recently taken from the animal, by diſſecting the membrane, ſo as to lay the vitreous humor perfectly expoſed, I then applied it to the hole made in the window-ſhutter of the camera obſcura, and I found according to the Carteſian experiments that the objects appeared manifeſtly in an inverted ſituation. Taking away the eye from before the opening, I applied in the place of it a convex lens, and I had the ſatisfaction to find the ſame inverſion of the object. A glaſs globe, nearly of the ſame diameter as the eye, preſented the ſame phænomena. A lens, concave on one ſide repreſented the objects in their erect ſituation.

Here

Here it is evident that the rays of light ſuffer by the influence of the intervening medium. The convex lens and a glaſs globe offer the ſame phænomena as the eye, which in this experiment ſeems to act on the rays of light by decuſſating them, juſt as the ſolid bodies above mentioned. It is evident beyond a doubt, that the rays of light do not decuſſate within the lens or the globe, but that theſe bodies attracting the rays of light unite them all into a focal point. The intervening medium loſing its force ſoon after, the rays of light by their own elaſticity purſue their right line till they eſcape from the interruption cauſed in their courſe, and continue in their uſual progreſſion. Why then are we to ſuppoſe that the eye has in this caſe the power to decuſſate the rays within the vitreous humor, more than in the other tranſparent bodies? By every experiment I could make, the eye, in this caſe, is in every reſpect to be compared to the other tranſparent bodies, nor do the rays of light paſſing through the vitreous and other humors of the eyes, decuſſate within the eye, but only when they have paſſed the focal point, which is always beyond the ſubſtance of the medium. The rays of light paſſing thro' mediums whoſe ſurfaces are even, are not altered in their courſe, but when theſe rays paſs thro' ſpherical or convex bodies, they unite into a focus, and paint the object in an inverted ſituation. But it is certain alſo, that the appearance in the ſituation of the object, thro' convex glaſſes, depends on the manner in which the ſpectator's eye ſees them. The greateſt certainty in the viſual laws muſt be drawn from the manner in which the eye is affected. It is obvious when we look at any object with a naked eye, that we ſee it in an erect and natural manner, as it is equally certain if we oppoſe a convex lens as a medium between the eye and the object, we ſhall then ſee the ſame object in an inverted ſituation, provided the rays of light unite in the focal diſtance before they reach the eye. For that the eye may be affected in two different extremes, by looking thro' a convex lens, will appear from the following experiment.

If the object A B, fig. 7, ſhould be ſeen through a convex lens C D, by a ſpectator's eye at the diſtance F, it will appear in its natural ſituation, for the rays of light not having yet reached the focal diſtance, are attracted by the eye F, and ſeen ſomething magnified under the angle F M N. But when the rays of light have penetrated beyond the focal diſtance of the lens, at G, the ſpectator regarding the ſame object at the diſtance K L, muſt ſee it in an inverted ſituation.

This experiment affords the moſt ſatiſfactory determination that can perhaps be produced, of the judgment of the ſoul, and the manner in which the eye is affected by external agents. And it muſt appear as evident to every obſerver alſo, that the eye, N°. 3.

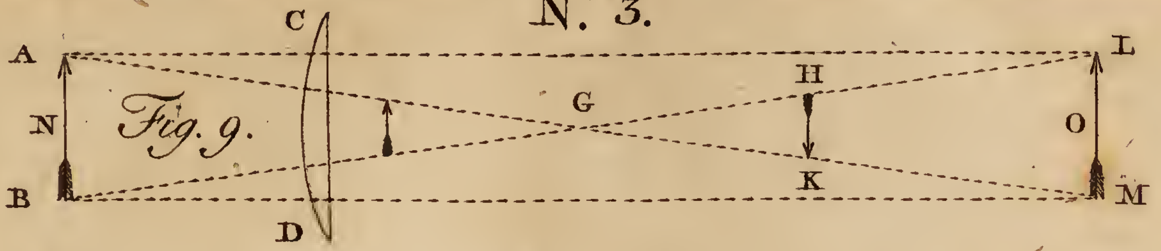


Fig. 9.

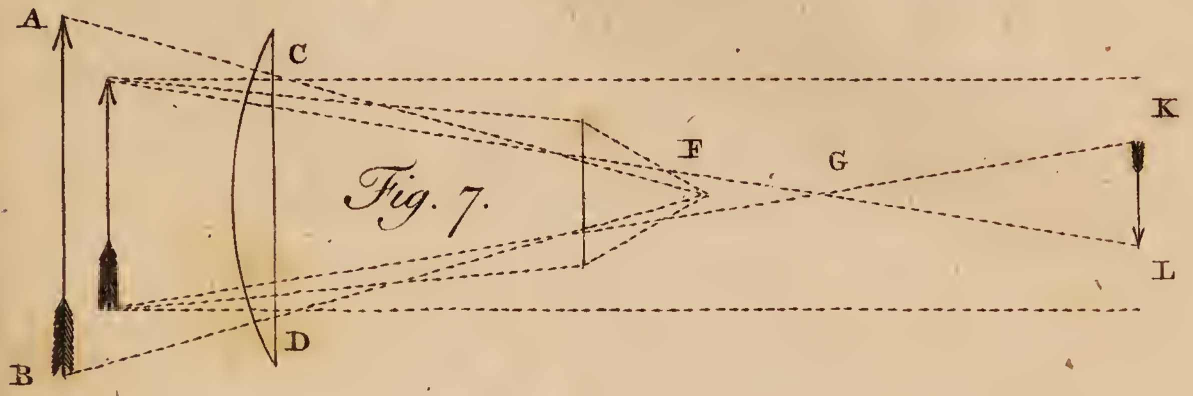


Fig. 7.

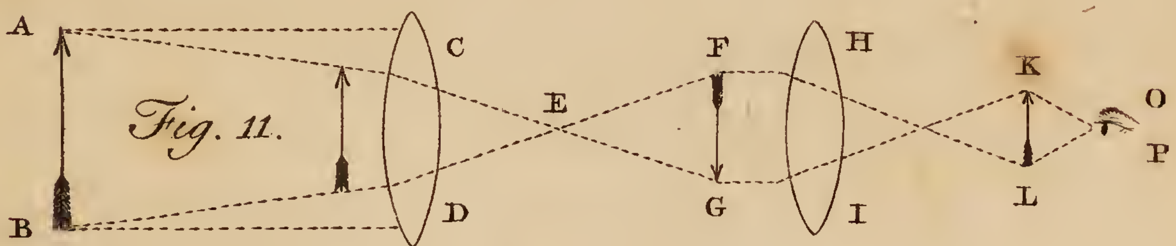


Fig. 11.

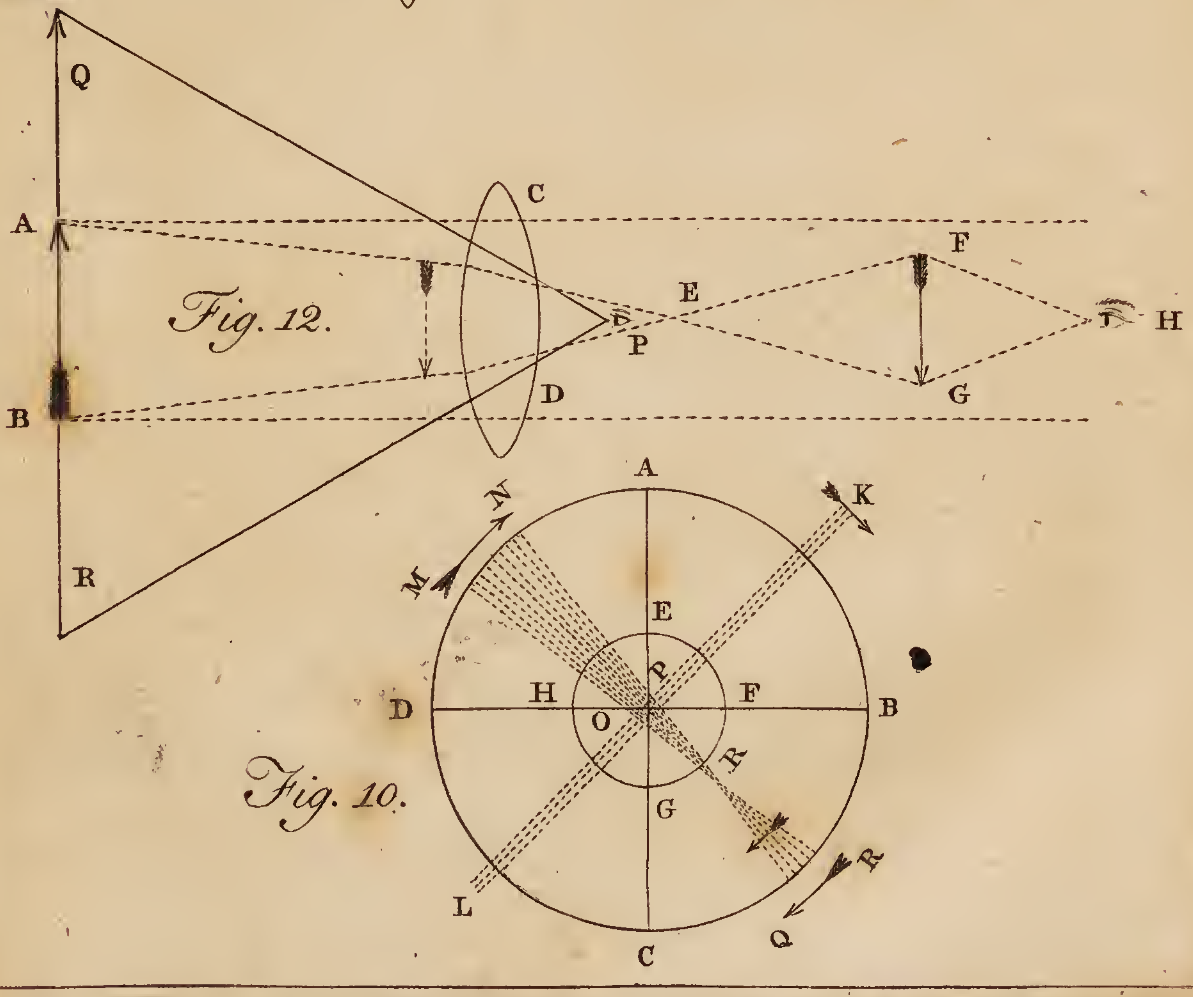


Fig. 12.

Fig. 10.

and the optic nerve do determine nothing of themſelves, but receive the impulſe of the rays of light in whatever manner they are directed. As a farther confirmation of this experiment, and in order to determine the true cauſe of the different affections of the eye by the above experiment, I placed a large dog on the ſeat of the window, but in ſuch a poſition that the ſubjects of the ſurrounding landſcape were clearly delineated on the tranſparent cornea. I then took a convex lens, which I held before his eyes, at ſuch a diſtance that the rays of light paſſing through the body of the lens might ſtrike on the cornea. I had the ſatisfaction to find I was not deceived in my conjectures. For the objects preſented themſelves firſt in an erect poſition when the lens was held at a ſmall diſtance from his eyes, and afterwards in an inverted one, when the lens was held ſo far from him, that the rays diverging from the focal diſtance, ſtruck on the membrane: I found alſo, that I could vary the ſituation of the object on the eye, as I pleaſed, either by the approaching or removing of the lens. It is neceſſary alſo to remark, that the animal gave ſome ſigns of a ſenſibility in one poſition of the object more than another, for I obſerv'd that he always retreated ſuddenly, when the union of the rays in the focal point ſtimulated his eye. To aſcertain as much as poſſible the validity of this experiment, I attempted it on the eye of a friend, to whom I communicated my thoughts, and anxious for the reſult of the experiment, conſented to my requeſt. Placing himſelf in a chair, I obſerved the delineations of the external objects on the tranſparent cornea, and on applying the convex lens, I ſaw its image on his eye, with the objects repreſented within its circle in their true ſituation; I aſk'd him in what manner he then ſaw the objects through the lens, he anſwered upright. Removing the lens farther, till the focal point affected the membrane, I aſked him the ſame queſtion, and he replied that he could diſtinguiſh no particular object, but only a confuſion of colors. Removing again beyond the focal diſtance, I ſaw the inverted icon of the object on the membrane, and aſking him in what manner he ſaw the objects through the lens, he anſwered, inverted. Could I poſſibly have a ſtronger proof that the viſual faculty of this organ, required no other repreſentations of objects than thoſe which were painted on the tranſparent cornea, to compleat the ſenſe of ſeeing?—A circumſtance much more eligible as correſponding with that natural elegance and ſimplicity which nature every where affects.

As I have always endeavored in my purſuits on this ſubject, to confirm as much as poſſible every experiment by obſervation, and where occaſion offer'd to confirm my obſervations by experiments, according to thoſe rules which Sir Iſaac Newton has left us in the Analyſis and Syntheſis. It remains at preſent only (to finiſh what I have ſaid on the inverſion of objects on the eye) to compare the ſyſtem of Kepler and Carteſius with my own obſervations in this laſt experiment.

It is the beautiful repreſentation of the objects on the retina, ſays Deſcartes, that gives us the idea of colors and the ſituation of objects in nature, for, ſays he, theſe objects are manifeſtly painted on the retina, and that not erect, but inverted, as the laws of optics require. But we find in this caſe, that the eye does not ſee the objects inverted but erect, and the reaſon is given in his ſixth chapter of Dioptrics as follows. "*Notitiâ illius ex nulla imagine pendet, nec ex ulla actione ab objectis veniente, ſed ex ſolo ſitu exiguarum partium ceribri, è quibus nervi expullulant.*"—Mr. Molyneaux in his Dioptrics ſays, That the eye is the organ or the inſtrument only, and that it is the ſoul that ſees by means of the eye. To enquire then how the ſoul ſees the object erect by an inverted image, would be to enquire into the ſoul's faculties.

But without enquiring into the ſoul's faculties, let us conſider it as an evident truth only, that the icon of all objects is painted on the tranſparent cornea, in their natural erect poſition. Carteſius and Kepler, as likewiſe all their ſectators, ſay, that all objects muſt be painted on the retina and alſo in an inverted ſituation, or elſe we can form no idea of the form, figure and ſhades of external objects. The Keplerians do not themſelves deny an erect ſituation of the objects on the cornea, but ſuppoſe there muſt always be a painting on the retina, oppoſed to that which is delineated on the cornea. So much granted, let us ſuppoſe the arrow A B, fig. 8. reflecting various rays of light from its ſurface, which are collected by the convex lens C D. On being removed at the appropriated diſtance from the ſpectator's eye, the diverging rays repreſent the object A B, in the inverted ſituation E F, on the cornea. The ſame rays, according to the Keplerian ſyſtem, ought to be refracted by the aqueous humor, which has that property, as being denſer than the ambient air. And according to the laws of refractions as before mentioned, the rays of light when paſſing from a denſe into a rarer medium, recede from the perpendicular in a contrary ſenſe. The rays of light then, having paſſed the aqueous humor, enter into a denſer medium in the cryſtalline, and approach by the ſame rules ſtill nearer to the central line, becoming more refracted: from thence paſſing into the vitreous humor, the medium of which is rarer than the cryſtalline, the rays of light receding from the perpendicular, paint the object on the retina in the inverted ſituation to that object on the cornea, and in the ſituation H G, as perfectly correſponding with its natural poſition at A B. But it is a certain and invariable truth, that if we look at any object through the medium of a convex lens, we muſt ſee it inverted, and oppoſed to its natural ſituation. The reaſon is evident. The rays of light which would otherwiſe be reflected from the object in right lines to the eye, are changed in their direction by the interpoſition of the lens, ſo that the ſpectator's eye looking back at the object by the means of the diverging rays, cannot avoid ſeeing the object in the poſition E F, as it paints itſelf on the cornea, nor can he ever ſee the object A B, in the direction H G. This is without doubt the moſt eligible reaſon that can be given why we ſee the objects inverted on the retina of the eye fixed to the hole of the camera obſcura. The rays of light are attracted to a focal point, as they are by the lens C D, and this is evident by the proof of the ſeventh experiment, for if the eye of the ſpectator be applied cloſe to the eye in the camera obſcura, he will ſee the objects in their natural poſition, and in an inverted one when beyond the focal diſtance. For the fact is, that the poſition of the object, as to its natural ſituation, is changed by the intervening medium. Neither can I allow that the icon of the objects is inverted on the retina of the eye. For it is certain, that objects are not inverted within the ſubſtance of a convex lens, as may be proved from ſeveral reaſons.

1ſt. From the diaphenity of its ſubſtance, which, according to the Carteſians, is owing to the rectitude and ſtraightneſs of its pores. For as the rays of light always proceed forward in ſtraight lines, they can only paſs freely and unaltered through thoſe bodies whoſe pores are in ſuch a direction, and this will appear more manifeſt if we conſider that the opacity of all ſubſtances are proportioned to the variation in the direction of their pores, or the compactneſs of the ſubſtance. For inſtance, the rays of light will paſs unaltered through limpid fountain waters, but throw into the fluid a ſmall quantity of the powder of galls, and the water will loſe its tranſparency, and become leſs capable of the admiſſion of the rays of light, for each particle of the galls which floats within the boſom of the fluid, intercept different rays of light, and make them either change their direction or recede back again. Throw again as much more of the powder of galls into the fluid as will render it opake, and you interrupt by that means ſo much of the light, that the body becomes impenetrable to the rays.

2. That the ſuperficial forms of mediums affect the rays of light. The rays of light do continually move by the progreſſion of right lines, without ever changing this direction, for ſhould they be intercepted by any opake body, they recede back again in a right line, forming only an angle, which is call'd the angle of reflection. When the rays of light are only altered in their courſe, by the different denſities of tranſparent mediums, they then change their firſt progreſſion only to form an angle which is call'd the angle of refraction. But although the different mediums are directors of the

rays of light, and may alter their primitive rectilinear direction, and make them change their uſual courſe, yet no intervening medium can ever make a ray of light move in a circular direction. But the ſuperficial form of all mediums has ſo much influence on the progreſſion of the rays of light, that we can vary their courſe as we pleaſe. For if I apply to my eye a tranſparent cube, or a common piece of glaſs, whoſe ſuperficial ſurfaces are planes, the rays of light will paſs through them unaltered, and ſhew me the object in its natural direction. But if I make uſe of a convex lens or a glaſs globe, the rays of light will then, by ſtriking on their peripheries, proceed in refracted lines to the common place of their union, which is called the focal point, from whence they will diverge until they eſcape the influence of the medium which changed their courſe, and will proceed again in their uſual direction invariably.

3. It is impoſſible that the inverſion of the object ſhould take place within the ſubſtance of the lens, ſince it would not only be impoſſible that the rays of light could change their direction within a medium whoſe reſiſtance could never be overcome by ſo feeble an agent as light, and moreover, the rays muſt always proceed in the ſame refracted direction, becauſe of the uniform denſity of the medium.

4thly. As the rays of light paſs through a tranſparent cube, or a common piece of window glaſs, uninterrupted, and without any viſible alteration by the ſubſtance, it follows that the poſition of any object reflected by the rays ſent from off its ſurface, undergoes no change although the rays have penetrated any diaphane cube, for the object is continually ſeen in its primitive direction. The rays of light move on, therefore, in their uninterrupted courſe, if oppoſed only by tranſparent bodies, whoſe ſurfaces are even and ſides parallel to each other.

5thly. But we are to remark, that theſe directions in the rays of light do never alter of themſelves, they are conſtant and immutable; it is therefore the form or poſition of certain objects alone, which vary their courſe. We are not, therefore, permitted to aſſert, that the rays of light have changed their direction, but we are to deſcribe the manner in which certain intervening bodies have altered their uniform progreſs.

If the rays of light paſs through a lens, one of whoſe ſides is a plane and the other a curve, they will receive no different modifications by the action of the medium. For in this caſe the rays are made to converge from their uſual courſe, by the curvilinear form of the medium, which diſperſes the rays of light as they eſcape, the object will, however, appear in its uſual poſition, by the means of thoſe parallel rays which are connected with the center of the medium, and which are not ſubjected to ſo great a degree of its action.

6thly. But there are mediums, whoſe action on the rays of light are ſo powerful, that they change the courſe of their direction entirely, and alter the natural poſition of the objects. Of this kind are all globular diaphane bodies, or any ſpherical or convex lens, whoſe ſides are the part of ſome ſegment of a circle, or its periphery. This is the moſt uncommon and ſurprizing phænomenon of the whole ſyſtem of optics. Its theory is the moſt difficult to explain, for which reaſon we ſhall endeavor to elucidate it in the moſt probable manner, and reduce it to certainty.—We beg leave to call to mind the invariable direction of the rays of light to a conſtant rectilinear progreſſion, and the poſſibility of their being diverted from that courſe by the power of certain inter-

intervening mediums. If therefore a cone of certain rays of light is reflected from the ſurface of an object as at A B, fig. 9 they move on in that rectilinear direction ſo long as the object remains viſible to the eye of a ſpectator, after which they rejoin the primitive current of light paſſing over our globe, to follow the general influence of the progreſs of its rays. For we are firſt to conſider, that the luminous particles which conſtantly emane from the ſun, paſs over the globe in continued right lines, as alſo that ſome of them are intercepted by the various objects diſperſed upon its ſurface, and become either abſorbed or reflected, by which means objects are rendered viſible to our ſenſes. The reaſon whereof is, according to Sir Iſaac Newton, That the rays of light which iſſue from a point of the object at N, are, by the axis of the glaſs croſſing the object, ſo refracted as to meet again about the point O. And the rays which diverge from the point A of the object, muſt meet again at almoſt the ſame diſtance from the glaſs, but on the other ſide of the axis, in the point M; for, ſays he, the rays at the glaſs croſs the axis.—In like manner, the rays which proceed from the point B, will meet about L on the other ſide of the axis.—But none of the rays, neither thoſe which proceed from the point N in the axis, nor thoſe which iſſue from A or B, will meet again exactly in one point; but in one place, as I here ſuppoſed at O, M and L, they will be crouded ſo cloſe together, as to make a diſtinct image of the object upon any body proper to reflect it, which ſhall be held there.—The rays of light which ſhould continue their courſe from A to L and from B to M immutably, being intercepted by the medium C D, become ſubject to its action. The ſpherical ſurface, by the peculiar influence on the rays of light, collect them more abundantly, and attract them with ſuch force, that they are conſtrained to unite, by their continued progreſſion, into a ſmall point at G, which is called the focal point. It is in this point that the force of the medium has exerted its greateſt action, and beyond which it has no longer any power of the rays of light, for by their own elaſticity they continue to diverge, by an oppoſed and contrary influence, to that which collected it to the focus G, and unravel themſelves till they arrive at the points L and M, where they are ſet free, and move on again in their primitive direction. But we are to obſerve, that the action of the medium C D, has ſo greatly alter'd the poſition of the object, that the arrow A B, is inverted at H K, and appears in a contrary ſituation to what it really is in nature. To account for ſuch phenomenon we are to obſerve, that the rays departing from the point A, ſtrongly attracted by the force of the lens CD, and following the rectilinear progreſſion from which they can never vary, are continued on to G and from thence to K. The rays departing from the points B, are by the ſame influence attracted to the point G, and from thence to H, by which it happens that the rays of light collected from the top of the object A, become the lower ones of the point K, as thoſe of B are the ſuperior ones at H. For this reaſon when the rays eſcape the influence of the medium, and expand themſelves, they repreſent the objects inverted as at H K. What is moſt material to obſerve relative to this circumſtance is, that the inverſion of any object, cannot poſſibly happen in optics, unleſs the rays have previouſly converged to a focal point, by the influence of a medium.

7thly. We ſhall endeavor to explain, (in a clearer manner) and to ſhew the true reaſon why globular, ſpherical, or curvilinear tranſparent mediums, have the peculiar property of collecting the rays of light into a focal point.—This circumſtance depends on that general proportion which all circles bear with reſpect to each other. For altho' their diameters may vary in any degree whatever, yet the circumference of the ſmalleſt

ſmalleſt is as capable of being divided into 360 degrees as the largeſt circle ever form'd. So that rays of light paſſing through circles of any magnitude whatever, and traverſing them at right angles, muſt divide them into 90 degrees each. To render it more intelligible let us ſuppoſe the circle A B C D, fig. 10, repreſenting the viſible horizon, as it appears to the eye of every individual, let E F G H, repreſent a glaſs globe placed exactly in the centre of the greater circle, having right lines ſeparating both the one and the other into angles of 90 degrees. Now if we ſuppoſe K repreſented a ray of light paſſing over the ſurface of the apparent horizon, it would follow the uſual courſe mark'd by the line K L, when uninterrupted by the power of a medium, according to what has been already aſſerted. But we are to conſider the rays of light as paſſing thro' the ſubſtance of mediums. Suppoſing, therefore, an aſſemblage of rays departing from the object M N, were expoſed to the attractive influence of the medium

H E F G, it would follow (as every portion of the larger circle A B C D, is repreſented in the ſmaller one E F G H) that any cone of rays departing from the object M N, would occupy a ſpace equal to ten degrees on the ſmaller circle, or on the ſurface of the globular medium E F G H, ſo as to occaſion a conſiderable contraction and diminution in the ſpace to which the cone of rays extended at M N, and at O P. For it is not poſſible that the rays of light can diverge at preſent, becauſe they are ſo forcibly enchained by the power of the medium, beſides they are on the point of entering into its ſubſtance, where the attraction becomes increaſed by the refractive powers of a denſer medium than the air, conſequently the cone of rays M N O P, are continually and forcibly drawn together, till no longer capable of contraction, they unite into the ſmalleſt point poſſible, which is the focal point R. The power of the medium having now exerted all its influence, the rays of light expand by the property of that elaſtic force which they conſtantly preſerve, and unfolding themſelves diverge to the ſpace of ten degrees on the larger circle, from whence they purſue their primitive rectilinear courſe. The variation in the diſpoſition of the object M N, at Q R, is the abſolute conſequence of that change which the cone of rays have ſuffer'd by the attractive force of the ſperical tranſparent medium E F G H, for we may obſerve that no ſuch change could happen in the poſition of the object if they were continued on without any interruption as at K L. It is likewiſe very eſſential to our deſign to remark again, that this inverſion in the poſition of the object cannot poſſibly take place, *or the rays of light diverge if they have not previouſly been collected into a focal point.*

8thly. Now the true diſtance of the focal point from any medium, is not to be determined by a general character, for it is found to vary according to the form or diameter of the medium. In globular bodies it is generally proportioned to their diameter. In convex lenſes it depends on the proportions which their curves bear with reſpect to each other, or the radii of their different ſegments, that is to ſay, the peripheries of the circles, of which their curvilinear ſides are a part.

9thly. It is a circumſtance of great moment to our general deſign, to know that as the focal point is ever beyond the agent, ſo the decuſſation of the rays of light can never happen within the body of the medium. For we have already remark'd in the ſixth propoſition, that the rays of light cannot diverge till they have paſſed the focal diſtance. Now the focal point is always without the medium, conſequently the rays of light muſt always decuſſate without the body of the medium alſo. Beſides, it is not poſſible that the rays of light attracted or reflected by the power of different agents, can ever exert a force ſufficient to to make them decuſſate in any medium denſer than the ambient air. For they are enchained by the force of the agent which governs them, and can never act of themſelves till the medium has ſpent all its force on them, and when they do diverge, it is only in conſequence of their natural elaſticity by which they expand: a force indeed too weak to oppoſe the refractive powers of a denſer medium than their natural element the air.

10thly. By the aid of different mediums, and their known action on the rays of light, we are capable of diſpoſing of the poſition of objects as we pleaſe. For example, If I would invert the poſition of the object A B, fig. 11. I make the rays which are reflected from its ſurface to paſs through the convex lens C D, and I find after they are collected in the focal point E, that the poſition of the object becomes inverted as at F G. Now if I would reſtore the object to its natural poſition, I collect the rays of light a ſecond time through another convex lens HI, and I find again when the object has paſſed the focal diſtance of the ſecond lens, that it is ſeen in its true poſition A B at K L. But we are to obſerve a ſmall difference in the firſt and ſecond attraction, for the firſt will throw the object in very beautiful colors on paper, in its inverted ſituation, but we cannot collect the image of the ſecond in its erect poſition on the ſame paper; it will however appear in its true and natural ſituation to the eye of a ſpectator placed at O P. *It appears evident therefore that we can diſpoſe of the rays of light as we pleaſe, by the aid of different mediums through which we collect them, or by which we reflect them back.*

11thly. The manner in which the eye is affected when examining objects through a convex lens, is another proof of the focal point being abſolutely detached from the ſubſtance of the medium, as alſo that the inverſion of the object never takes place till the

the rays of light have united in the focal point, by the active powers of the medium. We ſuppoſe the object A B, fig. 12, collected as in the foregoing experiment by the ſubſtance of the convex lens C D, united in a focal point at E, and inverted in its poſition as at F G. To the eye of a ſpectator placed in H, the object A B, will appear inverted as at E G, becauſe he ſees it when beyond the focal point at E, but was the ſpectator to place his eye at P before the union of the rays in the focal point E, he would ſee the object in its true ſituation A B, though conſiderably magnified, becauſe he ſees it under a much greater angle as P Q R, and if he placed his eye in the focal point, he would obſerve a confuſion of light without being able to diſtinguiſh the traces of any object. We are to obſerve in this experiment, that the eye is affected in three different manners: it ſees the objects firſt, in its true poſition A B, when placed at P; it ſees a confuſion of light without remarking the object, when placed at E; and inverted in the third poſition, when ſeen beyond the union of the rays in the focal point E.

12thly. It ſeems to me that the perfect appearance of any inverſion of the objects on the vitreous humor, or the proximity of the focal point to the body of the medium, can depend on no other cauſe than thoſe I have mentioned, I was induced therefore to make the following experiment. To the hole of the camera obſcura ABCD, (fig. 13) at F G, I applied a convex lens H I, and then found the focal diſtance of the object to be as marked in the firſt focus. When I applied a ſecond lens at K L, the focal point was ſomething nearer to the medium, as marked in the ſecond focus. The application of the third convex lens brought the focal point ſo near the body of the medium, that the inverted icon of the object was repreſented in the moſt lively manner poſſible on a piece of white paper, juſt the ſame as appeared on the vitreous humor of the eye of the ox, according to Mr. Kepler's experiment, and as mark'd in the third focus of the figure. It muſt be manifeſt to every obſerver, that there are no decuſſations of the rays within the ſubſtance of either of the three lenſes, and the effect is exactly the ſame as that produced by the eye of the animal, in which I can find nothing to prove that there is a real decuſſation of the rays within the body of the vitreous humor. However, if this experiment is not ſufficient to cauſe a doubt relative to the decuſſation of the rays of light within the eye, it will ſerve at leaſt as a ſtrong proof to confirm what has been already mentioned relative to the focal diſtance of mediums. When a fourth and fifth lens were applied, the icon of the objects ceaſed to appear, and all was a confuſed maſs of light without any determined figure. But when I applied a large object cloſe to the firſt lens H I, it could then be perceived through the fifth lens in an inverted ſituation.

From all theſe circumſtances taken together, I thought I might be allowed to conſider the inverted poſition of objects on the retina of the eye, as a chimerical hypotheſis only.—This induced me to inveſtigate the cauſe of viſion. I firſt began by denying, or at leaſt doubting of the inverſion of objects on the retina, and ſupported a theſis in the ſchools under the following title.—*Quædam Phyſiologicæ atque Dioptricæ contrà objectorum in retina inverſionem Objectiones.*—The matter though new was received without prejudice.

Encouraged by this ſucceſs, I began to examine my ſubject with more attention, and am now fully perſuaded that the decuſſation of the rays of light within the vitreous humor of the eye, is an abſolute error, conſequently the inverſion of objects a mere hypotheſis.

Since then the ſyſtem of viſion according to Deſcartes and Kepler may be erroneous, we ſhall next endeavor to propoſe one that ſhall be ſubject to no ſimilar inconvenience. With this intention we are to conſider the ſenſe of ſeeing as the pureſt ſentiment of contact with external objects. I mean, that the gentle ſtimulus of the rays of light on the optic nerve is the immediate cauſe of viſion.—No paintings of objects are requiſite, no inverted repreſentations of them intrude upon us, or require the influence of a rational innate ſentiment to rectify and contradict, but on the contrary all is uniform and ſimple.

We ſuppoſe an external object as A B, (fig. 14,) held up to the eye that conſiders it, and the cone of rays which are reflected from its ſurface, as contracted by the exter-

N.° 4.

Fig. 1. System of Vision according to Mr. Kepler.

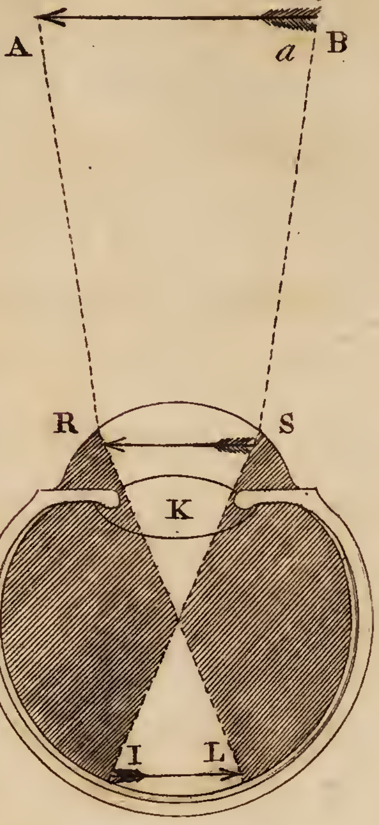
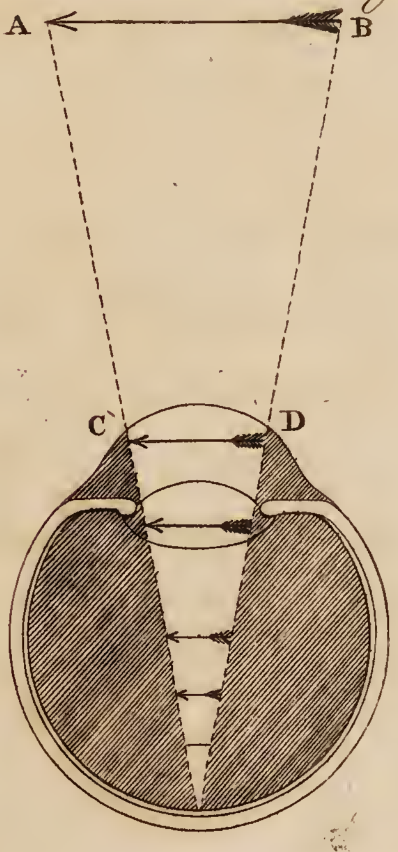


Fig. 14. System of Vision according to Dr. Berdoe.



nal form of the tranſparent cornea at C D. This contraction is the conſequence of the ſpherical form of the medium, that is to ſay, the periphery of the tranſparent cornea. As the rays of light enter the denſer humors of the eye, they are powerfully refracted, particularly ſo by the cryſtalline. But the vitreous humor from its denſity, (tho' not near equal to that of the cryſtalline) is too powerful in its action to admit of a decuſſation of the rays of light within its ſubſtance. For I have endeavored to prove in the 9th propoſition, that the rays of light can never exert their expanſive force beyond the focal point, when the medium is denſer than the ambient air.

The vitreous humor counterbalances the effect of the cryſtalline, for without the former the latter would repreſent objects to the optic nerve as prodigiouſly magnified. If our eyes were deprived of the vitreous humor, all objects would appear one hundred times larger perhaps than what they are, but then we ſhould not be able to ſee them at ſo great a diſtance from us. This circumſtance ſeems ſufficiently proved from what has been already aſſerted in fig. 7th, where we propoſed that an intervening medium might have a magnifying power when we look'd through it, and the object remain in its natural poſition and form.

It appears therefore that the external poſitions of objects are certain in themſelves, but that their ſituations and appearances may be varied in many different ways by the force of intervening mediums, deſtroying the uniform and rectilinear progreſs of the rays of light. The eye is not formed by the hand of nature, to vary the ſituations of external objects, but a medium to repreſent them to the human mind, as an immediate perception. The rectilinear progreſs of the rays of light are continued on to the optic nerve, by which means we ſee objects without variation.—Every phenomenon in the laws of viſion may be reconciled to this ſuppoſition,—The proof will furniſh matter for ſome future publication.

FINIS.

Plate No. 1, to front Page 20.
—— No. 2, —————— 44.
—— No. 3. —————— 48.
—— No. 4. —————— 76.

☞ The candid reader will excuſe the errors of the preſs.